obtained already by normal or "*trichromic*" eyes, if we suppose the "red" element of colour eliminated, and the "green" and "blue" elements left as they were, so that the "*red-making rays*," though dimly visible to the dichromic eye, excite the sensation not of red but of green, or as they call it, "yellow."

VIII. The extreme red ray of the spectrum appears to be a sufficiently good representative of the defective element in the colour-blind. When the ordinary eye receives this ray, it experiences the sensation of which the dichromic eye is incapable; and when the dichromic eye receives it, the luminous effect is probably of the same kind as that observed by Helmholtz in the ultra-violet part of the spectrum—a sensibility to light, without much appreciation of colour.

A set of observations of coloured papers by the same dichromic observer was then compared with a set of observations of the same papers by the author, and it was found—

1. That the colour-blind observations were consistent among themselves, on the hypothesis of *two* elements of colour.

2. That the colour-blind observations were consistent with the author's observations, on the hypothesis that the two elements of colour in dichromic vision are identical with two of the three elements of colour in normal vision.

3. That the element of colour, by which the two types of vision differ, is a red, whose relations to vermilion, ultramarine, and emerald-green are expressed by the equation

$$D=1\cdot198V+0\cdot078U-0\cdot276G,$$

where D is the defective element, and V, U and G the three colours named above.

IV. "Report to the Royal Society of the Expedition into the Kingdom of Naples to investigate the circumstances of the Earthquake of the 16th December 1857." By Robert Mallet, Esq., C.E., F.R.S.

(Abstract.)

The region examined in this expedition, embraces, in its widest extent, most of the country between a line drawn from Terracina to Gargano on the north, down to the Gulf of Tarentum on the south.

The earthquake, the greatest that has occurred in Italy since that of 1783, was felt over nearly the whole of the Peninsula south of Terracina and Gargano. Its area of greatest destruction (the meizoseismal area), within which nearly all the towns were wholly demolished, was an oval whose major axis was in a direction N.W. and S.E. nearly, and about 25 geog. miles in length by 10 geog. miles in width. The first isoseismal area beyond this, within which buildings were everywhere more or less prostrated and people killed, is within an oval of about 60 geog. miles by 35 geog. miles; the second isoseismal is also an oval within which buildings were everywhere fissured, but few prostrated and few or no lives lost. The third isoseismal embraces a greatly enlarged area, within which the earthquake was everywhere perceived by the unassisted senses, but did not produce injury. A fourth isoseismal was partially traced, within which the shock was capable of being perceived by instrumental means, and which probably reached beyond Rome to the northward.

The author divides his Report into three parts. In the first he has developed the methods of investigation which he pursued for the purpose of finding the directions of movement of the wave of shock at various points, and thence to determine—1st. The point upon the earth's surface vertically over the centre of effort or focal point, whence the earthquake impulse was delivered; 2nd, the depth below the surface (or rather sea-level) of the focal point itself. The line passing through both these points he calls the seismic vertical. The author points out, that of the three elements of the earthquake-wave, viz. the velocity of transit, the velocity of the wave-particle (or wave itself), and the direction of motion at each point of the seismic area, the first alone in other instances has hitherto been attempted to be determined, the velocity of the wave and that of its transit being apparently confounded, and any attempt at direction confined to the apparent path on the surface. He then shows that every displaced object is in fact a seismometer, and that the displacement of regular bodies, such as buildings or their parts, may be made, by examination of their conditions after the shock, and the application of the principles of dynamics, to give precise information as to the true directions in azimuth and angles of emergence at various points of the wave, and its velocity at those points.

The effects produced, which are mainly available for such determinations, he shows are divisible into four great classes :—1st. Fissures or fractures produced in buildings, from whose direction, &c. that of the wave-path at the point may be discovered: under this head the author has minutely described and figured the forms and peculiarities of fractures produced in all classes of buildings in the region examined. The principles deduced being universally applicable, he has shown the choice and precautions, &c. as to those best fitted for seismic observation, and given formulæ for the deduction of the wave-paths, *i. e.* the direction in which the wave movement at the point emerges. Velocity may also be determined from fissures; but this is more accurately ascertained from, 2nd, the overthrow of bodies, such as columns, piers, walls, &c., either fractured at their bases or simply overturned. 3rd. Fractures at the base without sensible movement, or with oscillation within an observed arc short of overthrow. 4th. The displacement of bodies by throw or projection, such as vases, finials, balustrades, bells, coping-stones, tiling, &c. from elevated points, in which, where the vertical height fallen, and the horizontal range are observed, the velocity can be determined or the direction of the wave-path and the angle of emergence of the wave; —in certain cases all of these classes of displacement may occur variously combined. All these resolve themselves into fracturing forces, the movements of compound pendulums, and those of projectiles; and in arranging the formulæ for application, the author acknowledges the important assistance rendered him by his friend the Rev. S. Haughton, Professor of Geology in the University of Dublin.

The author concludes the first part by a description of the characteristics of the towns and cities, buildings, &c. in the region examined, of the physical features, the orographic and surface configuration, and the geological structure of the south of Italy as embraced in his investigation.

The second part embraces the application of these methods of investigation, and the complete detail of the observations made by the author in his journey from point to point,—the working out at many separate points of the directions of the wave-paths and angles of emergence and wave-velocities,—the explications of the numerous and frequently singular and at first apparently perplexing circumstances, producing abrupt changes in the local intensity of seismic

effects observed,—the description generally of the places examined and phenomena observed, embracing many examples of fissures in earth or rock, falls of rock, landslips, changes of water-courses, &c., and the explanation of their conditions,—the observations continually made to correct the magnetic declination for the observations of wave-path by compass,—the hypsometric determinations by the barometer of many points of elevation,—geological sections over certain parts of the country examined,—the time observations obtained for determination of transit velocity. The descriptions are illustrated by numerous sketches made by the author on the spot, by diagrams and topical maps, and by a large series of photographs, made under the author's instructions, by a photographer who followed in his track.

In the appendices to this part the author has given translations of all the notices that appeared in the 'Giornale Reale' (the only Neapolitan newspaper), of the events of the shock, with tables of the meteorology of Naples, from those of the Royal Marine Observatory, for certain periods before, during and after the shock; also returns of the population, area, damage, deaths and number of wounded persons in the shaken provinces.

In the third and concluding part the author colligates all his facts, classifies them, and draws his conclusions and generalizations under the following heads:—

a. The superficial position of the seismic vertical. This, the author shows from the independent and concurrent evidence of above 70 separate wave-paths, was close to the village of Caggiano, near the E. extremity of the valley of the Salaris; the evidence being of a highly cumulative character, as the intersection of two wave-paths only is sufficient to determine this point.

b. The depth of the focal point below the sea-level. This, the author shows, was about $5\frac{3}{4}$ geographical miles, *i. e.* the *mean* focal depth.

c. The forms and areas of the meizoseismal and the several isoseismal curves. These have been laid down by the author upon three large maps, protracted from Zannoni's great map of the kingdom of the Two Sicilies, upon a scale of more than half an inch to the geographical mile.

Of these, the map A shows the wave-paths as determined in

azimuth, and their close concurrence at the seismic vertical, the position of all the points of observation, and the axial lines of the great mountain ranges. The map B gives the physical features of the country, and the four first isoseismal curves; distinguishing the injuries done to the numerous cities and towns, &c. by separate colours. Upon both maps the probable horizontal form of the focal cavity is marked, which coordinates with the existing lines of dislocation of the country in a remarkable manner. The map C gives the whole of the isoseismals for this earthquake, and compares them with the corresponding seismal curves (so far as these can be obtained from the narratives), for a number of the greatest earthquakes on record which have occurred in the Italian Peninsula, including that of 1783.

d. The effects of the physical configuration of the surface and formations beneath, on the progress of the wave of shock, are discussed, and the peculiar oval forms and the directions of the major axes accounted for.

e. The effects are pointed out, of the form and position of the focal cavity in modifying the distance of transmission of the wave of given effort in different directions.

f. Applies the results to showing the actual conformity of the isoseismal curves to the principles enunciated.

g. Under this head the author explains the nature of the separate system of wave-paths for Naples City, and the surrounding district, which only received the shock by transmission of refracted and transversal waves passed through the Monte St. Angelo range of mountains, with entire change of direction.

h. Colligates the facts ascertained as to the sounds heard with the shock at various points round the seismic vertical, and points out the remarkable relations that the prolongation of the sound more or less at different points bears to the direction in length and in depth of the focal cavity, and generally the causes of the diversity of sounds heard at various points around earthquake centres.

i. Discusses and points out the nature and correspondence with the dynamic laws of wave motions, of the tremors that preceded and followed the great shock, and generally the causes inducing such in all earthquakes.

k. Refers to the ascertained phenomena of reiterated or double

shock at certain places, and points out the combinations, having reference to surface configuration chiefly, producing such from a single central impulse.

Under the section *l*, the whole of the preceding information is combined, to deduce the dimensions, form and subterraneous position of the focal cavity, which the author shows to have been a curved lamellar cavity or fissure of about 3 geographical miles in depth by 9 geographical miles in length, with an inclined vertical section, and a mean focal depth (or depth of its central point of surface) of $5\frac{3}{4}$ geographical miles below the sea.

In section *m* are discussed, upon the data of hypogeal increment of temperature (as supposed to be ascertained from deep mines and artesian wells), the necessary temperature of the focal cavity, and the intensity of the force that acted within it to produce impulse, assuming that to have been due to steam at high tension, either *suddenly* developed or *suddenly* admitted into a fissure rapidly enlarged by rending.

n. Deduces the amplitude of the wave and the work stored up in it on reaching the surface, and compares the former with the observed amplitudes.

o. Deduces the velocity of transit of the wave of shock upon the surface, from the most trustworthy of the observations of *time* at various localities. These are found to correspond with considerable exactness, and give a transit rate of between 700 and 800 feet per second, as that at which the *wave form* was propagated from point to point, differing with change of formation by amounts stated.

p. Deduces the velocity of the wave itself, *i. e.* that of the wave particle, which is shown to have been in round numbers between 13 and 14 feet per second (in the direction of the wave-path). A remarkable relation is pointed out between this velocity and that recorded for the earthquake of Riobamba, the greatest whose effects have been observed. The height due to the velocity of this wave is to the altitude of Vesuvius as that due to the velocity recorded of the Riobamba wave is to the mean height of the volcanic shafts of the Andes, and more especially to the height of the volcanic vents nearest to Riobamba. The author points out that the *direct altitude* of a volcano is the true measure of the volcanic and seismic energy beneath it, and not its volume, which is a measure both of energy and time combined.

Under section *q*, he discusses the facts ascertained by him, as to the decay of the wave of shock in relation to superficial distance from the seismic vertical. The amplitude of the wave slowly and slightly increases, and its velocity decreases. The observations are not sufficient to admit of certain deduction as to what function of the distance the law of decay follows. The lowest velocity at nearly 30 miles from the seismic vertical was still about $11\frac{1}{2}$ feet per second.

Under *r*, the author has discussed systematically the facts ascertained as to the local disturbing causes producing abrupt perturbations of the wave of shock, and shown that they are:—

1st. Retardation by great fissures or faults, or deep valleys of dislocation; the effects of these, at about Muro and Bella, amounting almost to sudden extinction of the wave.

2nd. Alternate cutting off and partial extinction by parallel chains of mountains, and the effects of multiplied anti- and synclinals.

3rd. Increment and reduplication, with or without change of wave-path, by local reflection from mountain masses.

4th. Effects of free-lying surfaces (flanks and extremities of mountain ranges) and nodal points, and production of intersecting secondary shocks, and sudden reductions of energy by entrance of the wave to greatly increased masses.

5th. Effects of formation (geological), of change from one to another, &c.

6th. Effects of position of towns and cities on plain and hill, rock or loose material.

Towns on steep rock eminences, such as Saponara, are shown to have suffered from an extreme conjoint velocity, viz. that of the wave itself, and that of the hill-top, oscillating as an elastic pendulum.

Of all these modifying conditions, external contour of surface, and more especially the forms and directions, &c. of mountain masses and deep fissures, are shown to be the most efficient. The value is shown of contoured maps, models, or other such means of directing the mind to the true figure of the country, in seismic researches.

In the section *s*, the author arranges and discusses the facts observed by him, as to secondary effects produced by the earthquakes, under the heads of—

1. Earth fissures and landslips. These are in directions generally more or less transverse to the wave-paths, but conform to and are

determined by the dip or slope of the subjacent beds of rock. Earth fissures are *never* produced by the direct passsage of the wave of shock. They are a mere secondary result, and are no more than incipient landslips.

2. Rock shattering and falls.

3. Alterations of water-courses, muddying of springs, &c., all of which are shown to be due to the secondary effects of landslips into their beds, falls of partially loose rock therein producing ponding up and subsequent debacle.

The total modifying effects on the earth's surface are shown to be insignificant.

No great sea-wave accompanied this shock ; nor was such possible, the focal point being inland. The author examined with care more than 150 miles of sea-coast, as well as river-courses, for evidence of any permanent elevation of land having taken place concurrently with this earthquake, but found none. Earthquakes cannot produce elevations, although the latter have been known to have taken place about the same time as earthquakes and in the same region.

t. Discusses the meteorological phenomena, both during the earthquake or directly after it, and for a prolonged period before it. Some remarkable relations are pointed out between the disturbance of the annual rainfall previously and the occurrence of shocks.

The physical conditions concerned in widely alleged unusual meteoric light, diffused over the central portion of the shaken region at the night of the shock, and of the occurrence of oppressive heat, &c., are discussed ; and under *u*, the premonitory and other effects on lower animals, of nausea in men, &c., are considered.

v. Points out that the method of investigation pursued, enables deductions even now to be drawn from ancient fissures, &c., as to the focal centres of earthquakes occurring at very remote periods. In map D, the lines of loci of the focal points for the whole of the Italian peninsula are, as far as practicable, laid down, and their general connexion with the seismic bands of the Mediterranean Basin (as deduced from the British Association Earthquake Catalogue, and its accompanying Seismological Map of the World) is pointed out ; and some general relations both of the unequal distribution of the points of greatest energy along these seismic bands, and of the unequal evolution of energy at the same points, in long

periods of time, to the common origin of volcanic and seismic force, and its nature, are pointed out.

Some observations of a practical engineering character are added, as to the proper construction of houses, &c. in earthquake countries, by which the author is satisfied that the disastrous loss of life at intervals recurring might be avoided. In conclusion, the author returns thanks to various individuals for co-operation in the objects of his expedition, and most especially to his friends Dr. Robinson, Prof. Haughton, General Sabine, Sir Roderick Murchison, and Sir Charles Lyell.

June 7, 1860.

The Annual Meeting for the Election of Fellows was held this day.

Sir BENJAMIN C. BRODIE, Bart., President, in the Chair.

The Statutes relating to the Election of Fellows having been read, Sir Philip Egerton and Mr. Babbage were, with the consent of the Society, nominated Scrutineers to assist the Secretaries in examining the lists.

The votes of the Fellows present having been collected, the President announced that the following gentlemen were duly elected into the Society:—

Frederick Augustus Abel, Esq.
Thomas Baring, Esq.
John Frederic Bateman, Esq.
Edward Brown-Séquard, M.D.
Richard Christopher Carrington, Esq.
Francis Galton, Esq.
Joseph Henry Gilbert, Esq.
Sir William Jardine, Bart.
Thomas Hewitt Kev, Esq.
Joseph Lister, Esq.
Rev. Robert Main, M.A.
Robert William Mylne, Esq.
Roundell Palmer, Esq., Q.C.
John Thomas Quekett, Esq.
Edward Smith, M.D.

The Society then adjourned to Thursday, June 14.